Wetting (or Non-wetting) of Textured Surfaces

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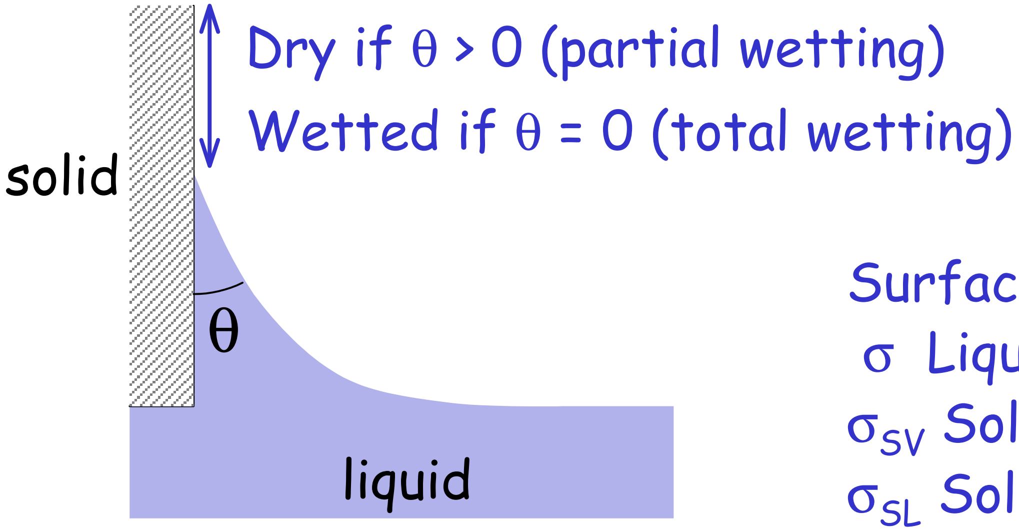
Wetting of an ideal flat surface



Surface tensions

σ Liquid/Vapor

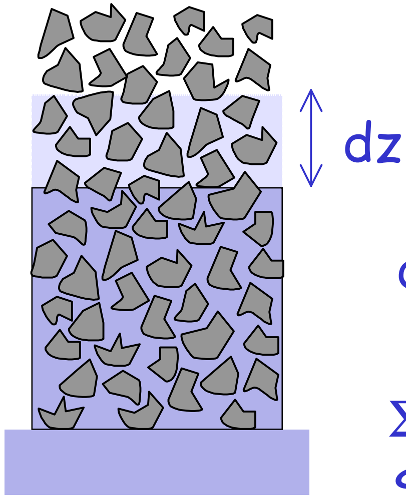
σ_{SV} Solid/Vapor

σ_{SL} Solid/Liquid

Young relation:

$$\cos\theta = \frac{\sigma_{SV} - \sigma_{SL}}{\sigma}$$

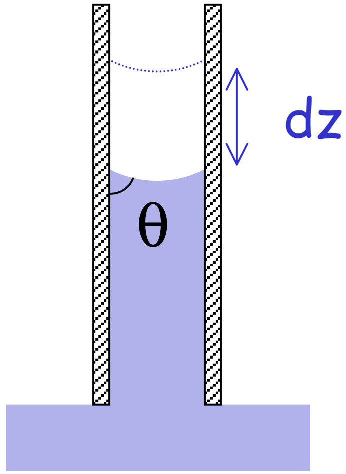
Imbibition of a porous media (or of a capillary)



$$dE = (\sigma_{SL} - \sigma_{SV})\Sigma S dz$$

Σ: specific area

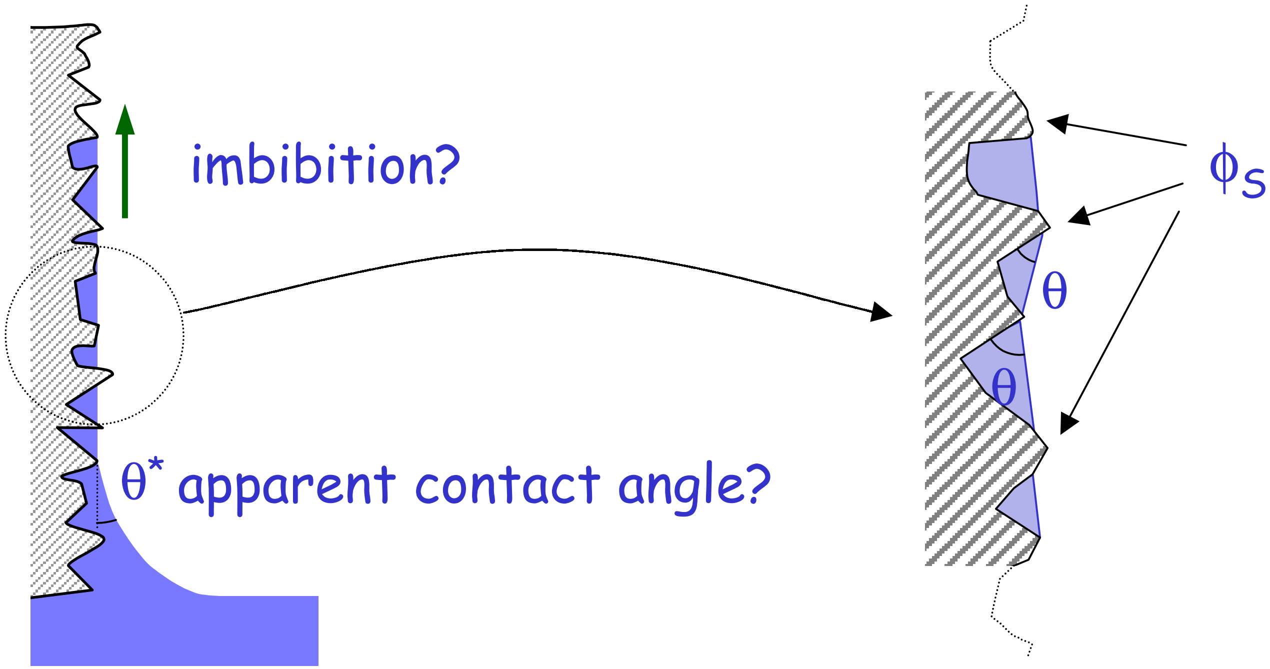
S: cross sectional area



Imbibition if $dE < 0$,

ie: $\theta < 90°$

Rough surface



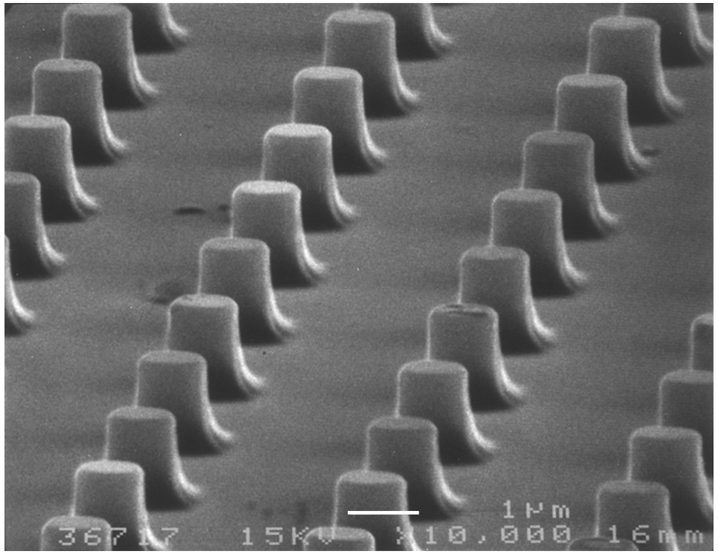
ϕ_S: surface fraction of the dry tops

r: actual area / projected

Ø complex in a general case

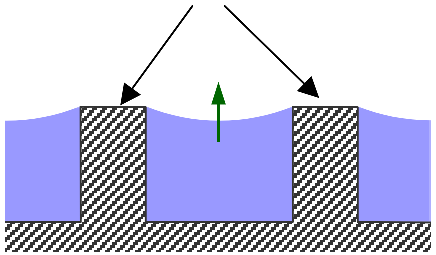
Textured surface

r and ϕ_S controlled

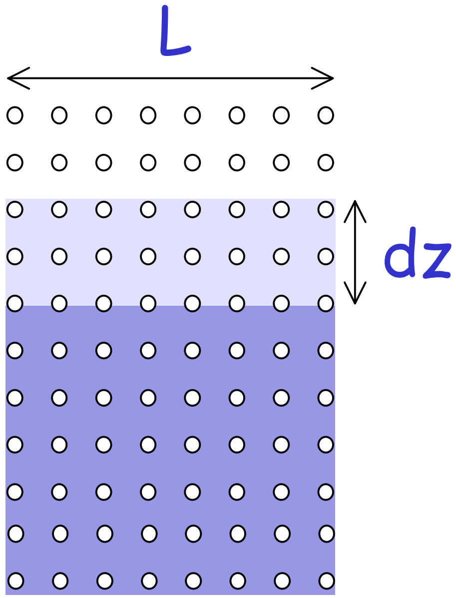


$r = 1.3$

$\phi_S = 5\%$



Imbibition of the texture?



$$dE = (\sigma_{SL} - \sigma_{SV})(r - \phi_S)Ldz + \sigma(1 - \phi_S)Ldz$$

imbibition if: $\dfrac{\sigma_{SV} - \sigma_{LV}}{\sigma} > \dfrac{r - \phi_S}{1 - \phi_S}$

ie: $\theta < \theta_c$, $\cos\theta_c = \dfrac{1 - \phi_S}{r - \phi_S}$

flat surface: $r = 1$ fl $\cos\theta_c = 1$, $\theta_c = 0°$

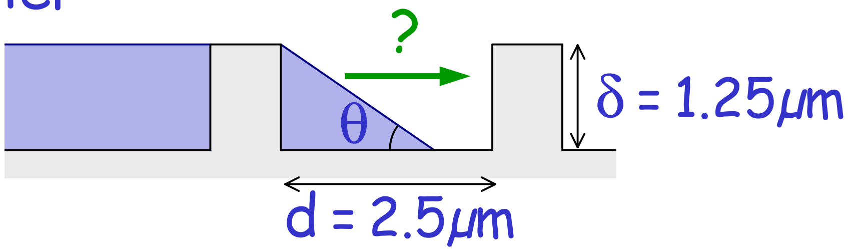
porous media: r Ø ¶ fl $\cos\theta_c = 0$, $\theta_c = 90°$

textured surface: $\theta_c = 40°$, experiment : imbibition for $\theta < 30°$

(θ measured on a flat surface of the same composition)

Hysteresis

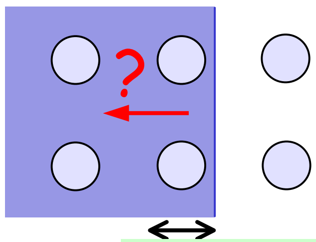
Jump over a barrier



extension of the meniscus long enough to reach the next row?

$\theta < \theta_a$, $\tan\theta_a$ ° δ/d $\theta_a = 27°$

Dewetting

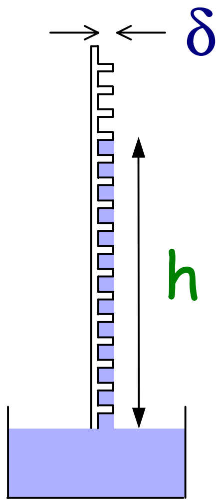


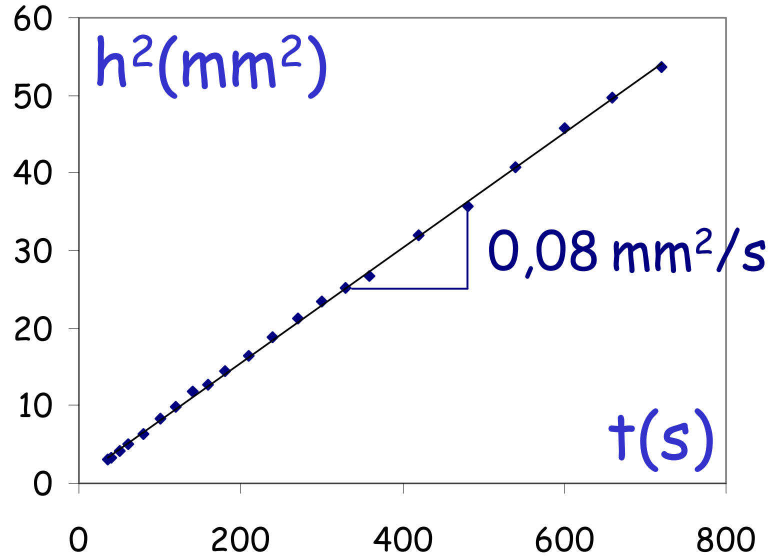
r and ϕ_S locally higher

experiment: dewetting for $\theta > \theta_r$, θ_r ° 60°

$r = 2$, $\phi_S = 20\%$ Ø $\theta_c = 63°$ (locally)

Dynamics of the imbibition





$\theta = 0°$, $\gamma = 20.6$ mN/m, $\eta = 16$ cP

Laplace pressure

$$\Delta P_L = \frac{\sigma}{\delta} \frac{\cos\theta - \cos\theta_c}{\cos\theta_c}$$

Viscous dissipation

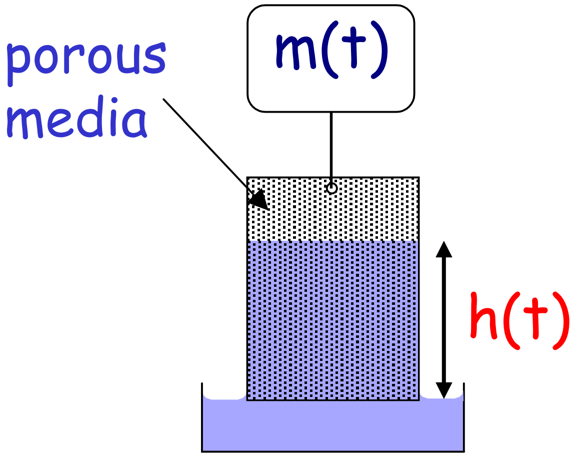
$$\Delta P_v = \beta \frac{3\mu V}{\delta^2} h$$

(β Ø 1 for a flat surface)

$$h^2 = \frac{2}{3\beta} \frac{\cos\theta - \cos\theta_c}{\cos\theta_c} \frac{\sigma\delta}{\mu} t$$

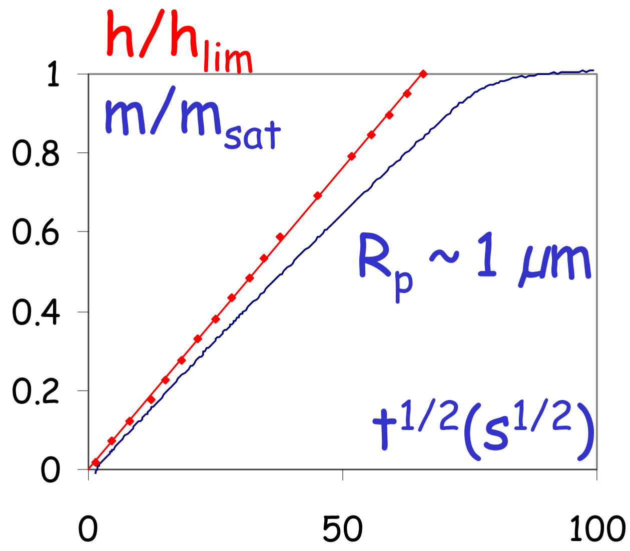
($\beta = 4.1$ from the fit)

Soaking of a porous material



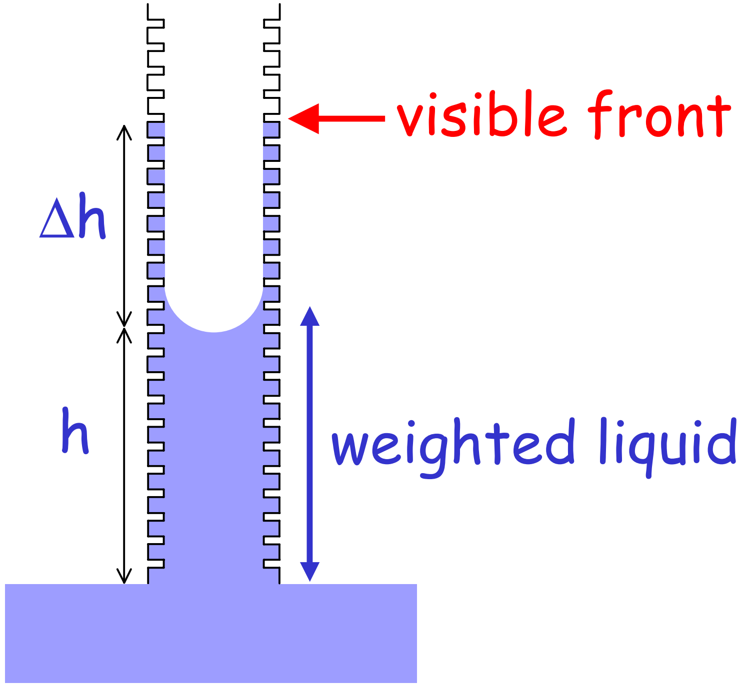
mean pore radius: R_p

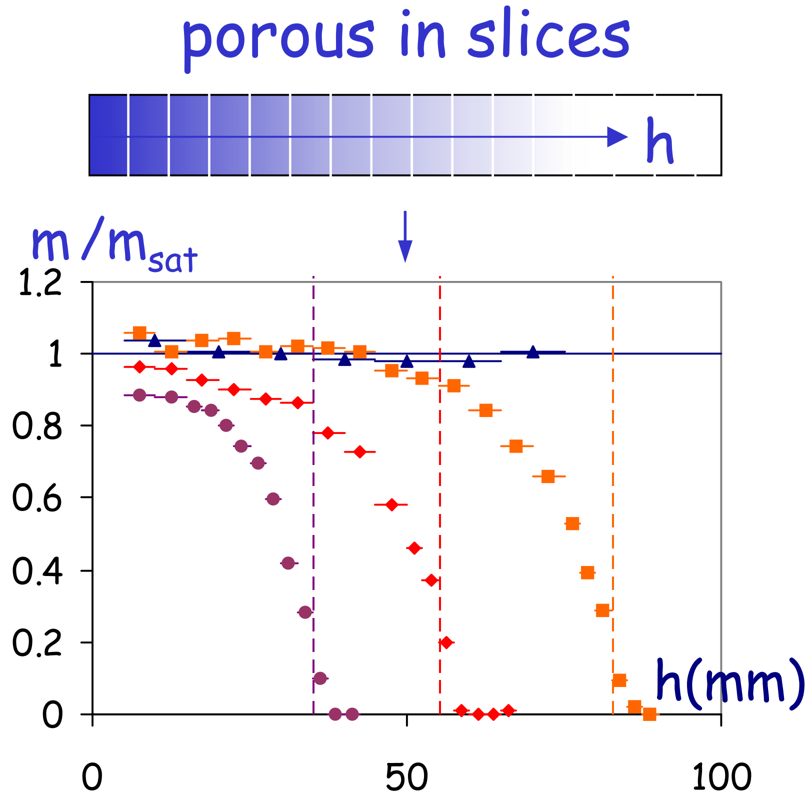
$$h^2 = \frac{R_p \sigma \cos\theta}{2\mu} t$$



2 pore sizes?

Textured tube



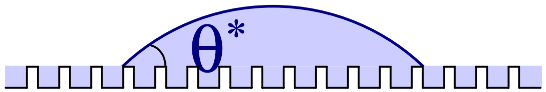


$$\frac{\Delta h}{h} \simeq \frac{\delta}{R} \frac{1 - \cos\theta_c}{\cos\theta_c}$$

big pores Ø reservoir for narrow pores

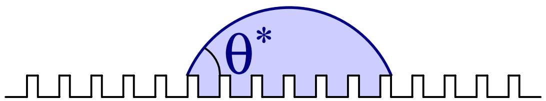
Contact angle

$\theta < \theta_c$ fl composite solid/water surface



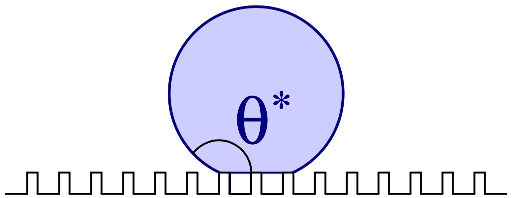
$$\cos\theta^* = 1 - \phi_S(1 - \cos\theta)$$

$\theta_c < \theta < 90°$ fl 'amplified' solid surface



$$\cos\theta^* = r\cos\theta$$

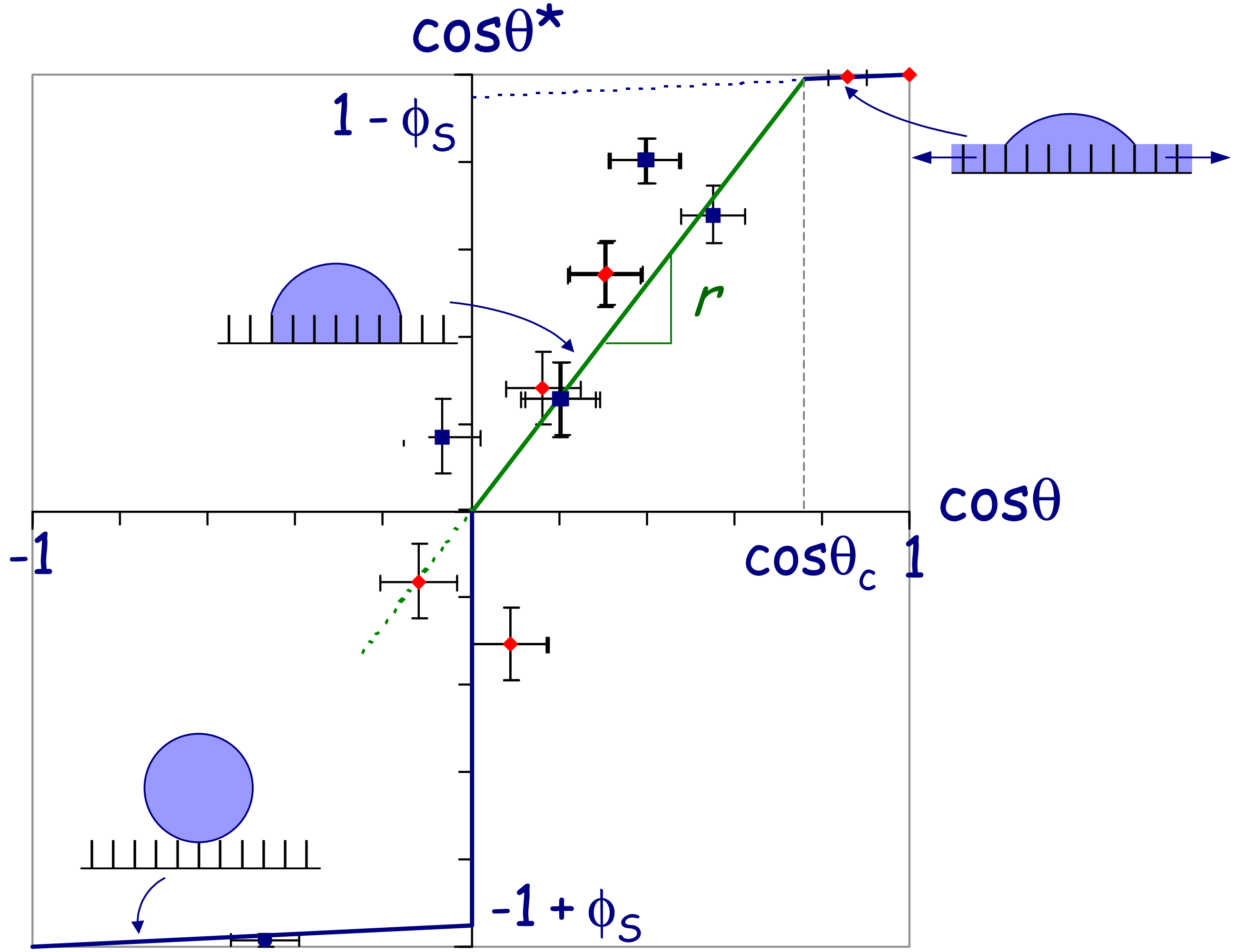
$\theta > 90°$ fl pearl drop



$$\cos\theta^* = -1 + \phi_S(\cos\theta - 1)$$

(θ: flat, θ*: textured)

Effective wetting diagram



Watering nanograss*

with K.B.K. Teo, M. Chhowalla, G.A.J. Amaratunga and W.I. Milne,
University of Cambridge, UK
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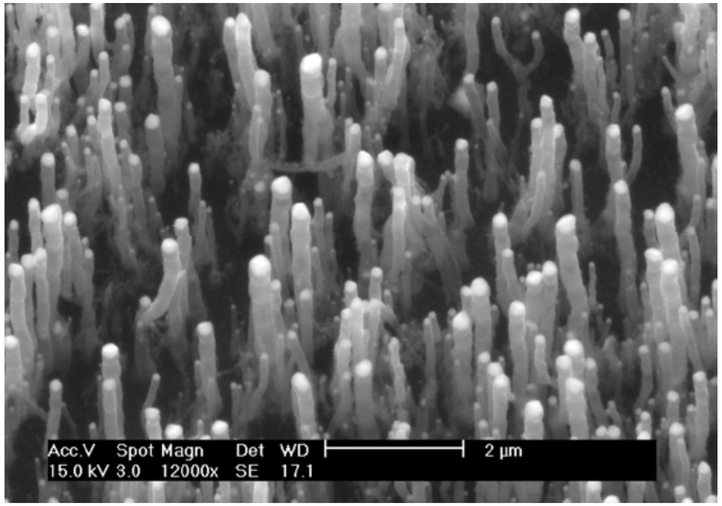
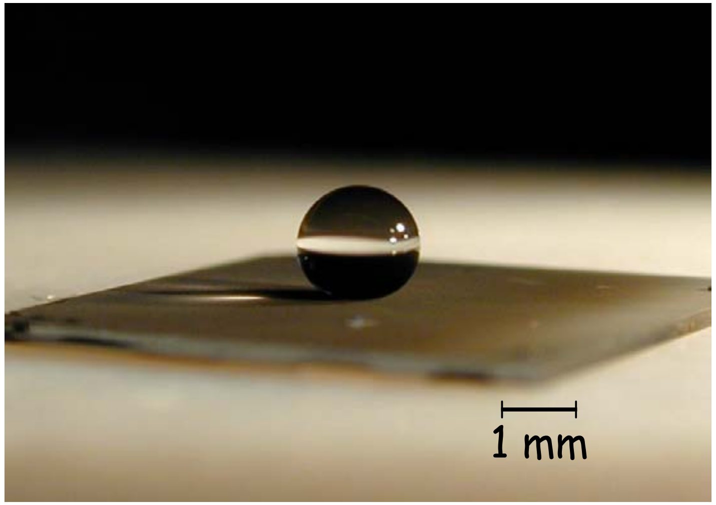


Carbon nanotubes surface
$r > 3$, $\phi_S > 4\%$



Drop at rest on a surface grafted with a fluorinated compound

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